lation of auxiliary steam plants to supply the deficiency during the three months adds so much to the yearly cost of the power in the way of interest, depreciation, insurance, and operation, as well as for fuel, that a power plant of this character can not usually compete with one not requiring an auxiliary plant.

The diversion of water from a stream is almost invariably so interrelated with other uses of water from the same stream, either present or future, that economic development of our water resources requires that each new use of water proposed, whether by diversion alone or by storage and diversion both, be considered in connection with all other possible uses of water from the same stream before the right is granted to construct. This is precisely what is done now in all the older countries where irrigation is practiced, such as Italy, France, and Spain.

To illustrate: If the irrigation interests of a valley or drainage basin appear, after a thorough consideration, to be superior to power interests—that is, of more value to the State—the granting of a power right on the stream below the irrigation lands should only be done as inferior to all subsequent diversions above for irrigation. If, on the other hand, after full consideration and with all the data essential to such consideration and study, it appears that the stream is more valuable for power purposes, then diversion for irrigation should be made inferior to power diversions.

If this is not done we may see the spectacle of a power plant worth, say, $1,000,000, on the lower course of a stream, holding up irrigation development above worth many millions. Even if the power right be condemned and the owners fully compensated for all expenditures and all values of the site as a power site, it will, nevertheless, have been an economic waste.

It will be said by some, "Let the fellow who gets there first have it. 'Finding is having.'" Now the facts are that the value of all water rights is made by the people and their increasing desire to use or utilize such resources. Should they not then at least have the privilege of saying in what manner the water right shall be developed? I have reference only to the value made by the people as a whole and not to the value added to the natural value by individual labor or effort. The individual right to this latter will hardly be questioned.

Any systematic development of water resources must include mining and navigation. The question of hydraulic mine tailings has been the cause of almost endless litigation in California. The interests of this State in river navigation where it will be affected by the use of water above navigation may, in years to come if not now, be greater than that of mining.

There comes under navigation the use of certain streams for logging. I know of a stream on which the logging interests are dominant through earlier use, at the expense of irrigation interests. It may be in this particular case that the logging interests should have the superior right—that the stream in that way yields a greater service to the State; but it may not, and we can conceive of a stream being held for logging purposes when it would be of infinitely greater value to the State as an irrigation stream.

Other water resources are artesian supplies and pumping from wells and streams for irrigation. Considerable has been done by the United States Geological Survey in investigation of artesian-well possibilities by study of the geological formations. Earlier bulletins by Russell and a later water-supply paper by Waring are valuable for reference in this connection.

WATER RESOURCES IN THEIR RELATION TO FORESTS.

Much has been said in the last few years of the value of forests in keeping up the summer flow of streams and thus benefiting both irrigation and power development. The radical supporters of forestry conservation will tell us that it hardly admits of argument. It certainly looks plausible, and yet you will find a great many of the hydraulic engineers of the country, if not indeed a large majority, of the opinion that the value of forests in preserving stream flow is very questionable.

Col. H. M. Chittenden of the United States Army Engineers, in a carefully prepared paper read before the American Society of Civil Engineers last year, refuted many of the arguments of the radical forestry advocates.

Mr. John R. Freeman, one of the most eminent engineers in New England, in an address before a meeting of engineers to consider conservation of national resources, said to his personal knowledge no perceptible change had taken place in New England streams from deforestation within his lifetime nor, so far as the available records show, since deforestation began.

Prof. Willis L. Moore, Chief of the United States Weather Bureau, in a carefully prepared report on The Influence of Forests on Climates and Floods, which was printed by direction of the Committee on Agriculture in the House of Representatives, states that the high waters in our rivers are not higher and the low waters are not lower than formerly, but, on the contrary, there appears to be a tendency in late years toward a slightly better low-water flow in summer. He, like most of the meteorologists, believes that the broken, cultivated, permeable soil is equally as good a conserver of rainfall as the forest area itself, and weather statistics favor the opinion of those who question the value of forests in preserving stream flow.

The following comparison of streams from forested and nonforested areas is from data prepared by John C. Stevens of Portland, Oreg., who was at the time assistant engineer of the United States Geological Survey, in charge of hydrographic investigations in Oregon and Washington:

A standard measure of the uniformity of flow is a very difficult thing to secure. For want of a better standard we may take the ratio of the maximum to the minimum discharge as the measure of uniformity. To show how it varies on different streams and under different conditions of forestation we will select a few streams in groups of two that drain both a forested and nonforested area and have nearly the same climatic conditions. As the intention is to show only relative conditions of flow, a single year's record is sufficient if simultaneous on the streams compared.

We will take for our first pair of streams the Donner and Blitzen River which flows into Harney Lake from the south and the Silvies River which flows into the same lake from the north. The Donner and Blitzen River drains the western slope of Steins Mountain and the watershed is without forest of any kind. The Silvies River, as the name implies, is quite heavily forested and it drains the southern slope of the Blue Mountains. The records of 1909 on both streams have been used. The highest discharge on Silvies River is 125 times the minimum flow and is in strong contrast to the even discharge of Donner and Blitzen River, whose maximum is less than 12 times the minimum.

We will take for our next pair of streams two which drain opposite sides of the Sierra Nevada Mountains in central California. Kings River drains the western slope and its entire area is heavily forested. Owens River drains the eastern slope and it is practically without forest of any kind. The soil of both is of granitic origin and the topographic features are not different. The rainfall on the Kings River drainage is a great deal more than on Owens River. On this account one would expect Owens River to present some of the features of arid region streams, but this does not appear to be the case. The discharge for 1906 has been used for both streams. The maximum discharge of Owens River is only 5 times the minimum while the maximum discharge of Kings River at the same time was 130 times the minimum discharge. The contrast is most striking and is all the more significant because the chief physical difference is that of difference in forest con-

ditions. Owens River is to be utilized as a source of future water supply for the city of Los Angeles and the surrounding country. Forestry enthusiasts have advocated the artificial forestation of its watershed to render the flow more uniform. If this comparison is any indication it would be well to let well enough alone.

We have compared two sets of streams, each possessing different conditions of forestation. Let us now examine three streams under the conditions existing on the plains of the Middle West. All three streams head in the foothills of the Rocky Mountains and flow eastward. The physical conditions as regard elevation, precipitation, and temperature are almost identical. Niobrara River flows from Wyoming across the northwestern part of Nebraska. Republican River flows from Colorado across the southwestern portion of the State. Frenchman River is a tributary of the Republican River from the north. All three watersheds are treeless. The first significant feature is that the ratio of maximum to minimum for all three streams without forests is much less than the corresponding ratio for the forested areas previously considered. The next significant feature is that the uniformity of flow among them differs widely. Plainly this can not be attributed to forests since there are none. The records for 1906 are used. The maximum discharge of the Niobrara was only 5 times its minimum. The maximum flow of the Republican was 34 times the minimum and of the Frenchman 11 times.

We will now compare three streams under forested conditions. For this purpose the Willamette River, draining the territory between the Cascade and Coast Ranges in Oregon, the Deschutes River, which parallels the Willamette River on the east side of the Cascade Mountains, and the Crooked River, which is a tributary of the Deschutes River from the east, will be taken. From the summit of the Cascade Range eastward the rainfall and consequently the stand of timber diminishes until the ascending slope of the Blue Mountains is reached, where the rainfall and stand of timber increases. Westward from the summit of the Cascade Mountains the rainfall diminishes to the Willamette River, then increases to the maximum at the summit of the Coast Range. The forests cover the entire drainage area of the Willamette River to the very banks of the river except where it has been removed by man. This area is one of the most densely forested areas in the United States. The logging that has been done has been confined to the lower altitudes and the forests of the water-producing portion of this area are still in their primeval state. On the watershed of the Deschutes River practically no timber has been cut, but only about 60 per cent of its drainage area may be considered as forested. Crooked River, which is its principal tributary, drains the western slope of the Blue Mountains. On its headwaters the forests are almost as dense as those on the headwaters of the Deschutes River. Now note the great difference in uniformity of flow from these three forested areas. The records of 1909 have been used and it is seen that the maximum of Deschutes River is only 5 times the minimum. On the Willamette River the ratio is 57, and on Crooked River 111 for the same period.

It is to be regretted that there are so little data upon which to make a more complete analysis of the conditions of flow on these streams. Knowledge of the rainfall is incomplete, and only very meager information is available as to the condition of the soil. There is no doubt, however, that if we could place all these streams on the same basis we would find that the heavily forested areas would deliver less water in proportion to the amount of rainfall received than the nonforested areas. In fact it has been shown from recent experiments in Switzerland that the run-off from forested areas is frequently but 60 per cent of that from cleared watersheds, all other conditions being the same.

It is admitted by all, I believe, that the total run-off of a stream is lessened by forests. On any stream devoted to irrigation or power, therefore, where storage is provided for the entire run-off of ordinary low-water years, the forests might be very detrimental. The time will come when several streams of eastern Oregon will be thus provided with storage for all the run-off of ordinary years. Forests would not have aided the Hondo reservoir nor the Sweetwater reservoir before mentioned. On the other hand it must be admitted that the forests tend to prevent erosion of the ground and thereby materially delay the filling up of the reservoirs with silt.

I mention these things only to call attention to the many sides of water conservation. I do not wish it understood that I am opposed to reasonable forest conservation. I believe that the forests, both public and private, are peculiarly a natural resource in which the whole people have a vital interest. I would even suggest the advisability of requiring lumbermen to reseed and maintain one acre for every acre logged, if the interests of the State would be thus best served.

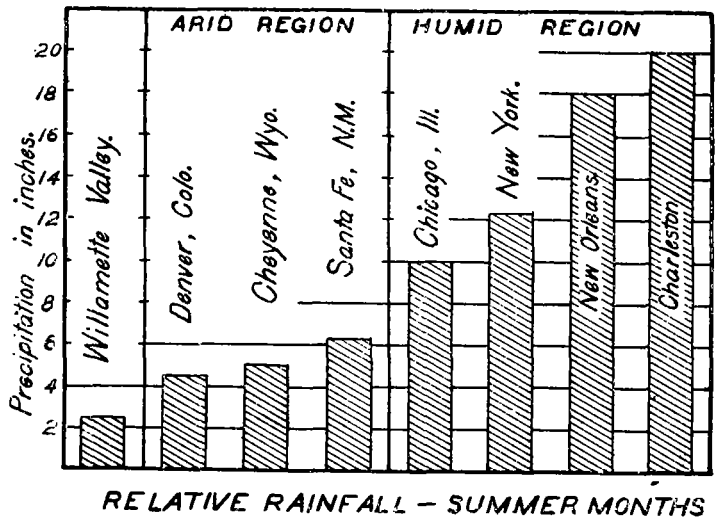

FIG. 1.